Robotics I

April 2, 2014

Exercise 1

Consider a robot with four revolute joints, having the Denavit-Hartenberg parameters of Table 1.

i	α_i	a_i	d_i	θ_i
1	$\pi/2$	$a_1 > 0$	$d_1 > 0$	q_1
2	$\pi/2$	$a_2 > 0$	0	q_2
3	$-\pi/2$	0	$d_3 > 0$	q_3
4	0	$a_4 > 0$	0	q_4

Table 1: Denavit-Hartenberg parameters of a 4-dof robot

- Sketch the robot and the associated Denavit-Hartenberg frames in two different configurations: *i)* $\boldsymbol{q}_A = \mathbf{0}$, and *ii)* $\boldsymbol{q}_B = \begin{pmatrix} 0 & \pi/2 & -\pi/2 & \pi/2 \end{pmatrix}^T$.
- Provide the symbolic expression of the direct kinematics map $\boldsymbol{p} = \boldsymbol{f}(\boldsymbol{q}) \in \mathbb{R}^3$ for the position $\boldsymbol{p}$ of the origin of frame 4.

Exercise 2

For the robot of Exercise 1, find the joint torque $\boldsymbol{\tau} \in \mathbb{R}^4$ that balances a force ${}^0\boldsymbol{F} = \begin{pmatrix} 0 & 10 & 0 \end{pmatrix}^T$ [N] applied to the origin of frame 4, when the robot is in the configuration $\boldsymbol{q} = \boldsymbol{q}_B$. Keep the symbolic dependence on parameters that are not specified numerically.

Exercise 3

Plan a smooth minimum time trajectory $q_d(t)$ for a robot joint that provides rest-to-rest motion from $q_{in} = 90°$ to $q_{fin} = -90°$, with velocity and acceleration equal to zero at the initial and final instants and satisfying the bounds $|\dot{q}_d(t)| \leq 90°/\text{s}$ and $|\ddot{q}_d(t)| \leq 90°/\text{s}^2$. Give the final expression of $q_d(t)$ and plot approximately this solution trajectory and its first and second time derivatives. Provide also the minimum feasible time T and the maximum absolute value attained by the velocity and by the acceleration.

[180 minutes; open books]